[redacted]

869 03076

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: AAP CM-SM Heater Control Electronics - Case 620

DATE: March 21, 1969

FROM: G. M. Yanizeski

ABSTRACT

North American Rockwell is proposing new heater control electronics for the AAP CM-SM. The presently baselined scheme includes redundant, fully automatic circuits employing bi-metallic thermostats. In the proposed AAP scheme, a mercury capillary is used on small heaters and a proportional controller is used on large heaters to limit power surges. A cursory examination indicates that the change to new control electronics is not strictly needed but desirable. North American feels that cost and scheduling deltas will be small.

(NASA-CR-106893) AAP CM-SM HEATER CONTROL ELECTRONICS (Bellcomm, Inc.) 7 p

N79-72388

Unclas
00/18 11644

BCS 03073

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: AAP CM-SM Heater Control Electronics - Case 620

DATE: March 21, 1969

FROM: G. M. Yanizeski

MEMORANDUM FOR FILE

North American Rockwell is proposing new heater control electronics to supplant the presently baselined scheme. The question has been asked by Mr. Schneider as to whether the change is needed. To quickly evaluate the change, and answer this question, the following three control schemes are compared: 1) the Apollo Block II scheme, 2) the presently baselined scheme, and 3) the newly proposed scheme.

In Block II, two basic circuits are used: 1) simple on-off manual control and 2) single thermostat control. Both systems are redundant, and both require instrumentation monitoring during normal operations. The thermostats are bi-metallic "on-off" devices. (See Figure 1 for schematics of the various circuits).

In the longer AAP missions, the decrease in available crew monitoring time in the CM, coupled with the large number of heaters required for the fixed attitude environments, creates a need for more reliable (long life), fully-automatic controls. The present baselined system represents an effort to fulfill this need employing Block II type equipment; however, more thermostats are used, and the wiring is different than in Block II. To illustrate (Figure 1), the Block II manual circuit has no thermostats and the Block II single thermostat circuit has redundant control with one thermostat each, while the AAP baselined scheme has redundant control with three thermostats each (a total of six). Two parallel thermostats control temperatures within the desired range and a third thermostat, in series, acts as a "thermal breaker" to protect against runaway heaters. This fully automatic scheme does not require crew monitoring during normal operation, and it is considered by North American to be more accurate, faster, and more reliable than the Block II scheme.

The baseline system has several shortcomings. The two major problems seem to be: 1) the control is "bang-bang" or "on-off" causing power surges, and 2) although the baseline scheme is considered more reliable than Block II, a failure in the series thermostat would effectively eliminate an automatic control circuit. With an open failure, heater power is lost, and with a closed failure, protection from a runaway heater is lost.

The new scheme, proposed by North American, would either solve or greatly reduce these problems. In addition, as indicated in Figure 2, the new scheme is better in other respects such as accuracy and response. (Accuracy may be important for PVT gauging.)

In the new system, different control electronics would be used on small and large heaters. There are approximately 15 to 20 small heaters (<45 W.) and 10 to 15 large. On small heaters, a mercury capillary (thermometer) with solid state switching is proposed. The device has a reliability of 0.9998, is very accurate, and such devices have been used on other spacecraft such as Mariner 4 and the LM RCS. It is an "on-off" control, but with the small heaters, this is not a drawback. For the large heaters, a proportional controller, such as a resistance temperature device with a bridge circuit connected to an amplifier, is proposed. This device is very reliable (0.9998) and accurate, and it would proportion power to the heaters thus eliminating the power surges. In addition, the failure mode is an open circuit thus eliminating the need for a thermal breaker and the corresponding threat of a runaway heater.

It is relatively clear that the new system is much better than the baseline system. However, whether the change is needed or just desirable seems to depend primarily on the chances of thermostat failure and on the importance of power surges.

According to the North American AAP Failure Modes Effects Analysis Document, thermostat failure has a "low probability" of occurring. This seems to be confirmed by the successful operation during Apollo flights 7 and 8. Therefore, although the problem certainly exists, the probability of failure seems to be low enough to accept.

Power surge problems are difficult to assess, but it is clear that large power margins must be maintained to accommodate the sudden starting of large heaters. For example, the largest heater is 255 watts. The proportional controller would substantially reduce the needed margin, although average power usage would not change appreciably for the mission. Although the surge problem may be solvable, North American indicates that the design difficulties are substantial.

Thus, a cursory examination indicates that the change to new control electronics is not strictly needed, but desirable. To finalize an evaluation of this change, a measure of its impact on scheduling and cost is needed. At this point, no comprehensive information along these lines is available; however, North American feels that cost and scheduling deltas are small, especially when they are balanced against savings in electrical power system redesign. This seems reasonable since even the presently baselined system is significantly different from Block II in design and in the number and type of heaters controlled. (Only 10% of the Block II heaters have been retained.)

On May 1, 1969, North American is required to submit a study justifying the heater control electronics change.

The author would like to acknowledge the help of B. W. Moss in this evaluation.

G. M. Yanizeski

1022-GMY-mef

G. M. Yanizeski

Attachments
Figures 1 and 2

COMPARISON BLOCK II & AAP THERMAL CONTROL SCHEMES

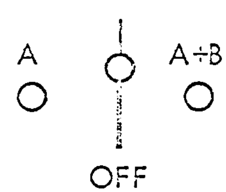
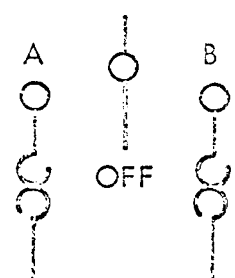
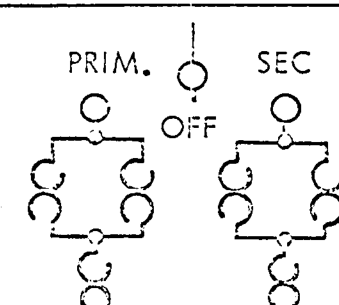
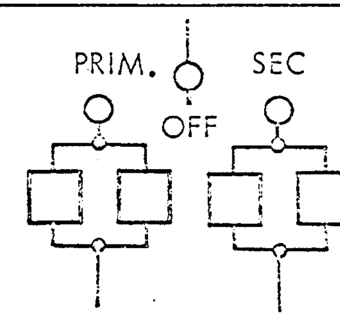
TYPE	PURE MANUAL CONTROL	SINGLE THERMOSTAT CONTROL	MULTIPLE THERMOSTAT CONTROL	ELECTRONIC CONTROL
USED ON	B-II SPS/ECS	B-II SM RCS	AAP BASELINE	AAP
INSTRUMENTATION MONITORING REQUIRED FOR NORMAL OPERATION	YES	YES	NO	NO
TEMPERATURE DEADBAND (LIMITS)	LARGE	LARGE	MEDIUM	SMALLEST
ACCURACY	LOW	LOW	FAIR	EXCELLENT
EFFECTIVE ON WHAT TYPE OF SYSTEM RESPONSE	SLUGGISH	MEDIUM	FAST	FAST
RELIABILITY (LIFE)	LOW	MEDIUM	GOOD	EXCELLENT
FAILURE MODE	OPEN/SHORT CIRCUIT	OPEN/SHORT CIRCUIT	OPEN/SHORT CIRCUIT	OPEN CIRCUIT
HEATER CONTROL CIRCUIT (SWITCH & CONTROL)	 A OFF A+B	 A OFF B	 PRIM. OFF SEC	 PRIM. OFF SEC
DESIGN LIMITS 40-85°F	FULL LIMITS	FULL LIMITS	50-65°F PARALLEL 72°F SERIES	63-67°F

Figure 1 - CONTROL ELECTRONICS COMPARISON CHART FROM NR PDR, FEBRUARY 10, 1969.

RECOMMENDED HEATER CONTROLLERS

- LOW WATTAGE HEATERS
  - HG THERMOSTATS WITH SOLID STATE SWITCH
  - RELIABILITY – 0.9998
- HIGH WATTAGE HEATERS
  - PROPORTIONAL ELECTRONIC CONTROLLER

RESISTANCE TEMPERATURE DEVICE WITH BRIDGE CIRCUIT	THE RTD MAY BE EXTENDED TO CONTACT A RELATIVELY LARGE AREA OF THE TEMPERATURE CONTROLLED COMPONENT (TANK), WHILE A THERMOSTAT WILL ONLY SENSE A SMALL CONFINED AREA. THE RTD WILL AVERAGE TEMPERATURE OVER A LARGE AREA. LOCAL SENSORS WILL HAVE TO BE STRATEGICALLY PLACED BETWEEN HOTTEST & COLDEST POINTS
POWER DEMAND REDUCED	WHEN THE SENSED TEMPERATURE APPROACHES THE REFERENCE (CONTROL) TEMPERATURE, POWER TO THE HEATER IS REDUCED PROPORTIONATELY, & EXCURSIONS & OSCILLATIONS DIMINISH
EMI	ON-OFF ACTIVATION OF THERMOSTATS OR BANG-BANG CONTROLLERS GENERATE EMI PROBLEMS
ENVIRONMENTAL CAPABILITY	-100 TO +200°F
AVAILABILITY	SEVERAL VENDORS HAVE SPACE QUALIFIED CONTROLLERS
RELIABILITY	0.9998 RELIABILITY WITH REDUNDANT CIRCUIT ELEMENTS
ACCURACY	UP TO 0.01°F CONTROL POSSIBLE
DEADBAND	LESS THAN 1/2°F IS OBTAINABLE
FAIL SAFE DESIGN	OPEN CIRCUIT FAILURE MODE
PVT GAGING	OPTIMIZED BY AVERAGING TEMPERATURES

FIGURE 2 - DESCRIPTION OF NEW CONTROLS FROM NR PDR, FEBRUARY 10, 1969.

BELLCOMM, INC.

Subject: AAP CM-SM Heater Control Electronics - Case 620

From: G.M. Yanizeski

Distribution List

NASA Headquarters

Messrs. H. Cohen/MLR
P. E. Culbertson/MLA
J. H. Disher/MLD
Acting Director/MLO
L. K. Fero/MLV
J. P. Field, Jr./MLP
T. A. Hanes/MLA
T. A. Keegan/MA-2
M. Savage/MLT
W. C. Schneider/ML

Bellcomm

Messrs. A. P. Boysen
D. A. Chisholm
D. R. Hagner
B. T. Howard
J. Z. Menard
I. M. Ross
J. W. Timko
R. L. Wagner
All Members Depts. 1021, 1022, 1024, 1025
Department 2034 Supervision
Department 1024 File
Central File
Library